CHAPTER 8

TRANSFORMER INSTALLATIONS

8-1. Definitions.

Transformers are classified in various ways according to their construction and application. In order to clarify usage in this manual, transformer terminology is defined in the glossary. Additional transformer definitions and terminology can be found in IEEE Std C57.12.80.

8-2. Installation of Distribution-to-Utilization Voltage Transformers.

a. Aerial mounting.

(1) *Unit capacities, mountings, and types.* Aerial transformer installations may utilize a three-phase unit or banked single-phase units. Transformers, either singly or in banks, having an individual unit or combined capacity greater than 300 kVA will not be mounted on single wood poles. Special structural considerations will be given for single-pole installations greater than 100 kVA. Pole-platform mounting (two-pole structure) will not be used, except where other mounting methods are not satisfactory. Cluster mounting for transformer banks is preferred over crossarm mounting as less visually objectionable. Similarly, the cluster or three-phase bracket mountings will be permitted for mounting of surge arresters and cutouts if acceptable to the Using Agency responsible for the operation and maintenance of transformer installations. Figures 8-1 and 8-2 indicate transform bank installations. Self-protected transformers have internal primary fuses that must be replaced by experienced personnel. Therefore, self-protected transformers will not be specified.

(2) *Location.* Aerially mounted installations may supply several buildings. When that is the case, transformers will be installed at the pole location closest to the building with the greatest load. Secondary wiring should drop directly to the buildings served, if the span does not exceed 125 feet; otherwise, intermediate poles are required.

b. Ground level mounting.

(1) *Types and capacities.* Ground-level mounting may be either the pad-mounted compartmental type or the unit substation type. Figures 8-3 and 8-4 show a typical pad-mounted compartmental transformer installation. Figure 8-5 shows a typical secondary unit substation transformer installation. The use of conventional-type (pole-mounted) transformers, with connections to separate primary and secondary protective devices, is not permitted since this type of installation is more dangerous, generally more difficult to maintain, requires more space, and there is rarely a significant cost saving since fencing is required. Pad-mounted compartmental transformers may only be used outdoors even when designed for both indoor and outdoor installation. Unit substation transformers may be used indoors or outdoors.

(2) *Pad-mounted compartmental liquid-insulated transformers.* Three-phase pad-mounted compartmental transformers may be applied in ANSI standard sizes through 2500 kVA, except that they will not be used where the primary voltage exceeds 15 kV or where fault currents are so large that standard equipment does not provide the required primary interrupting duty. The choice between pad-mounted, compartmental transformers and unit substations in conjunction with integral or non-integral load-center transformers will be based on: the application; potential for expansion; short circuit and protective device coordination; sound engineering judgment; accepted industry practice; and the operating, maintenance and reliability considerations listed below.

(a) If instruments and switches are routinely used by operators, choose unit substations and integral or non-integral load-center transformers. For pad-mounted compartmental transformers, instruments and operating devices are inside a locked compartment and are not readily accessible.

(b) Pad-mounted compartmental transformers require use of a switch stick for switch mechanism operation and cable-disconnection (due to the dead-front requirement). The typical high-voltage switch used with unit substations does not require use of a special tool and is therefore easier to operate.

(c) Fan cooling and 12 percent additional capacity for 55/65 degree C temperature rise is available for unit substations and integral load-center transformers, but is not available for pad-mounted compartmental transformers which are self-cooled; fans cannot be added to increase the cooling capacity.

(3) *Residential service.* Pad-mounted transformers will be routinely used in residential and light commercial service.

(4) *Industrial service.* Pad-mounted transformers may be used for industrial, commercial, or industrial application, provided that only one building is served; metering and secondary switchgear can be located in the building; and short

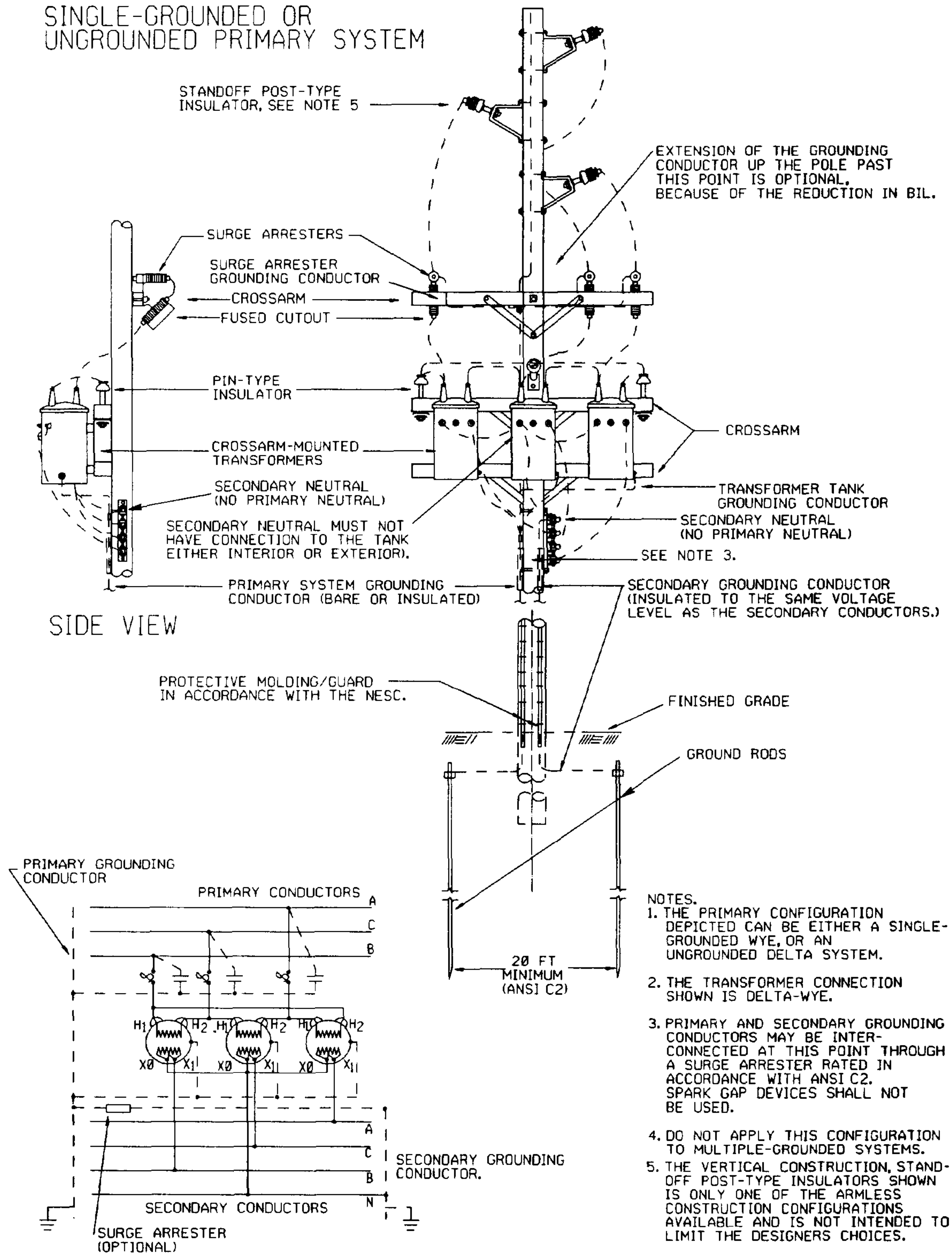
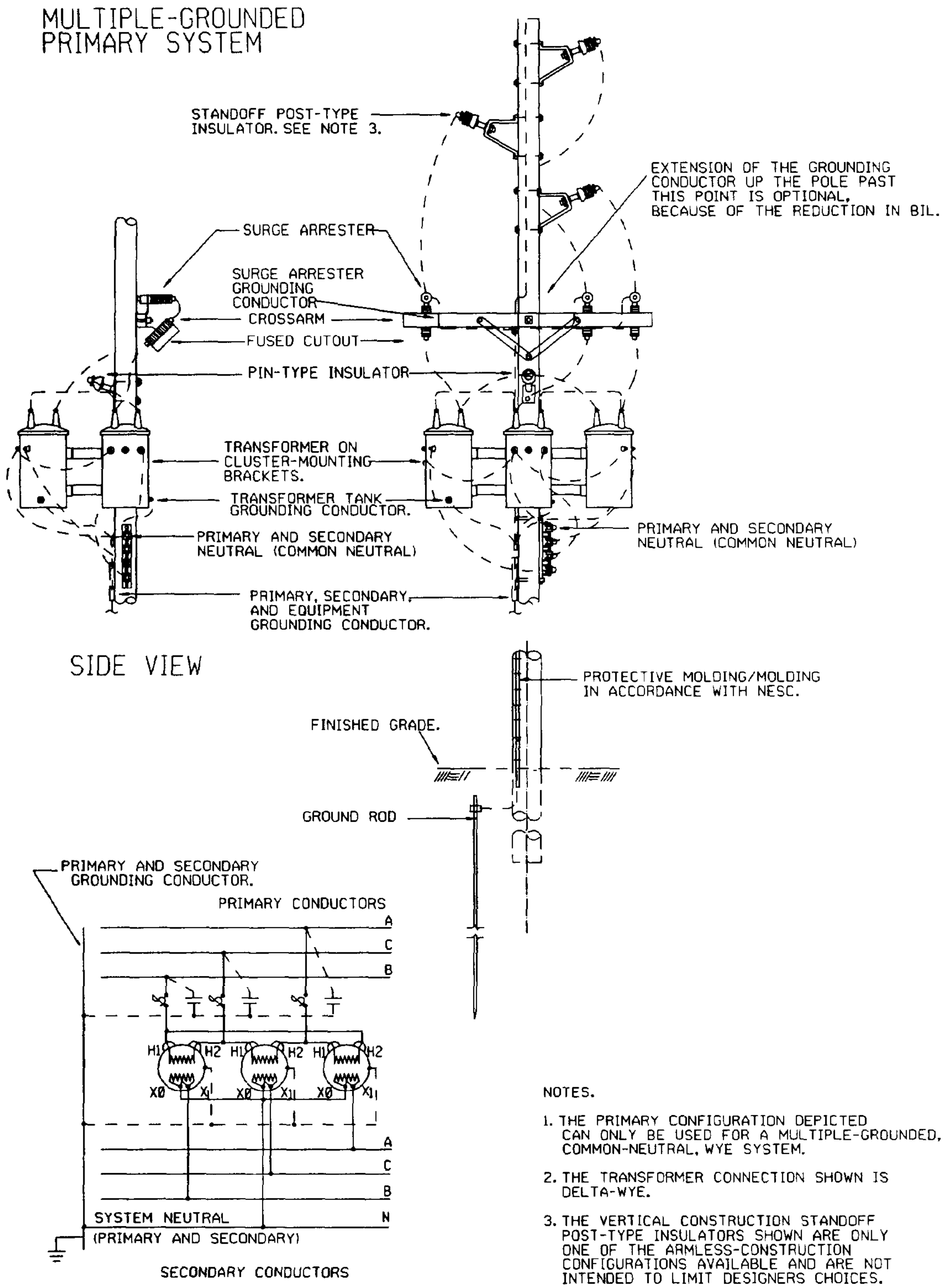


Figure 8-1. Cluster-Mounted Transformer Bank Installation.



NOTES.

1. THE PRIMARY CONFIGURATION DEPICTED CAN ONLY BE USED FOR A MULTIPLE-GROUNDED, COMMON-NEUTRAL, WYE SYSTEM.
2. THE TRANSFORMER CONNECTION SHOWN IS DELTA-WYE.
3. THE VERTICAL CONSTRUCTION STANDOFF POST-TYPE INSULATORS SHOWN ARE ONLY ONE OF THE ARMLESS-CONSTRUCTION CONFIGURATIONS AVAILABLE AND ARE NOT INTENDED TO LIMIT DESIGNERS CHOICES.

Figure 8-2. Crossarm-Mounted Transformer Bank Installation.

circuit and protective device coordination constraints are met.

(5) *Service for large loads.* Unit substations and integral and/or non-integral load-center transformers will be used for industrial, heavy commercial, and institutional applications involving large loads, multiple building serves, and the requirements for secondary bus protective devices.

(6) *Secondary unit substations.* Secondary unit substations with integral or nonintegral outgoing sections will be used. Since neither type is tamperproof, fencing is required. Fence height will be in accordance with the NESC. Transformers larger than 1,500 kVA for 480Y/277 V service and 500 kVA for 280Y/120 V service should be avoided, because of the magnitude of their secondary fault currents. However, in some cases, it may be more feasible and cost effective to provide 2,000 kVA transformers for 480Y/277 V service and use current-limiting fuses in conjunction with circuit breakers to limit secondary fault currents. The using agency (for Air Force, the Host/REQ CMD) will stipulate demand meter requirements.

(7) *Location.* Exterior installations are preferred over interior installations because space costs are less; however, secondary feeder lengths may require an interior location or make interior installations economical in some cases.

(a) Liquid-filled transformers installed outdoors. Outdoor installations will comply with the NEC, MIL-HDBK-1008A, and the NESC. Transformers will be located to preclude any reasonable chance that products of combustion from a transformer tire will be drawn into the HVAC air intake of adjacent buildings. The location of pad-mounted transformers will be compatible with the architectural concept and protected from vehicular traffic. Architectural compatibility will be obtained by the proper location in relation to landscaping, the addition of shrubbery around the transformer, or the use of screened fence enclosures. The primary service will be underground from pad-mounted transformers. Secondary building connections will use underground cables or bus duct; however, the use of more than six underground cables per phase in parallel will not be permitted since complexity of connection can lead to maintenance and space problems.

(b) Liquid-filled transformers installed indoors. Indoor installations will comply with the NEC and MIL-HDBK-1008A. Transformer vaults will be located on the exterior wall of the building, vented to the outside and accessible only from outside the building under normal design conditions. Air intake fans and louvers of heating, ventilating, and air conditioning (HVAC) systems will be interlocked with the smoke and rate-of-rise detectors in the transformer vault and/or vault rooms. The smoke and rate-of-rise detectors will de-energize the HVAC air intake if a fire occurs in the transformer vault and/or vault rooms. This is not necessary if the HVAC intake is located on the roof or the opposite side of the building from the transformer vault. A sign will be posted on the access doors to a transformer vault which indicates the appropriate fire fighting equipment and procedures. Pipes and ducts will not be routed above indoor transformers.

(c) Dry-type transformers. Dry-type transformer applications will comply with the NEC and MIL-HDBK-1008A. Dry-type transformers will be located to preclude any reasonable chance that products of combustion from a transformer fire will be drawn into the building's HVAC system. Dry-type transformers in ventilated enclosures may be specified for indoor applications in clean, dry environments (not subject to blowing dust, excessive humidity, or corrosive atmosphere) and will be rated for the highest temperature of the location. Dry type transformers in non-ventilated enclosures may be used for indoor or outdoor applications, if the enclosure is rated for the environment. Hermetically-sealed dry transformers (filled with dry nitrogen) will not be specified due to their large size, the inability to add supplementary cooling, and problems associated with loss of gas. Transformers protected by cast- or impregnanted-epoxy-resin may be used indoors and outdoors, where environmental conditions would shorten the life of a conventional dry transformer. Specifications will include epoxy encapsulation for the core and for both the high and low voltage windings. Each connection insulation must be compatible with the environment. The specification for medium-voltage primary transformers will require the basic insulation level to be the same as for liquid-filled transformers in the same voltage class, and will require the transformers to be tested in accordance with applicable ANSI tests for liquid-filled transformers.

c. Underground Mounting. Transformers in underground vaults are not permitted except where required to meet airfield clearances. Requirements are given in chapter 7 for equipment in underground vaults.

8-3. Installation of Transmission-to-Distribution Voltage Transformers.

These transformers are installed as part of the main electric supply station, since the secondary voltage will be of the 15 kV class or larger. Primary unit substation transformers will be used

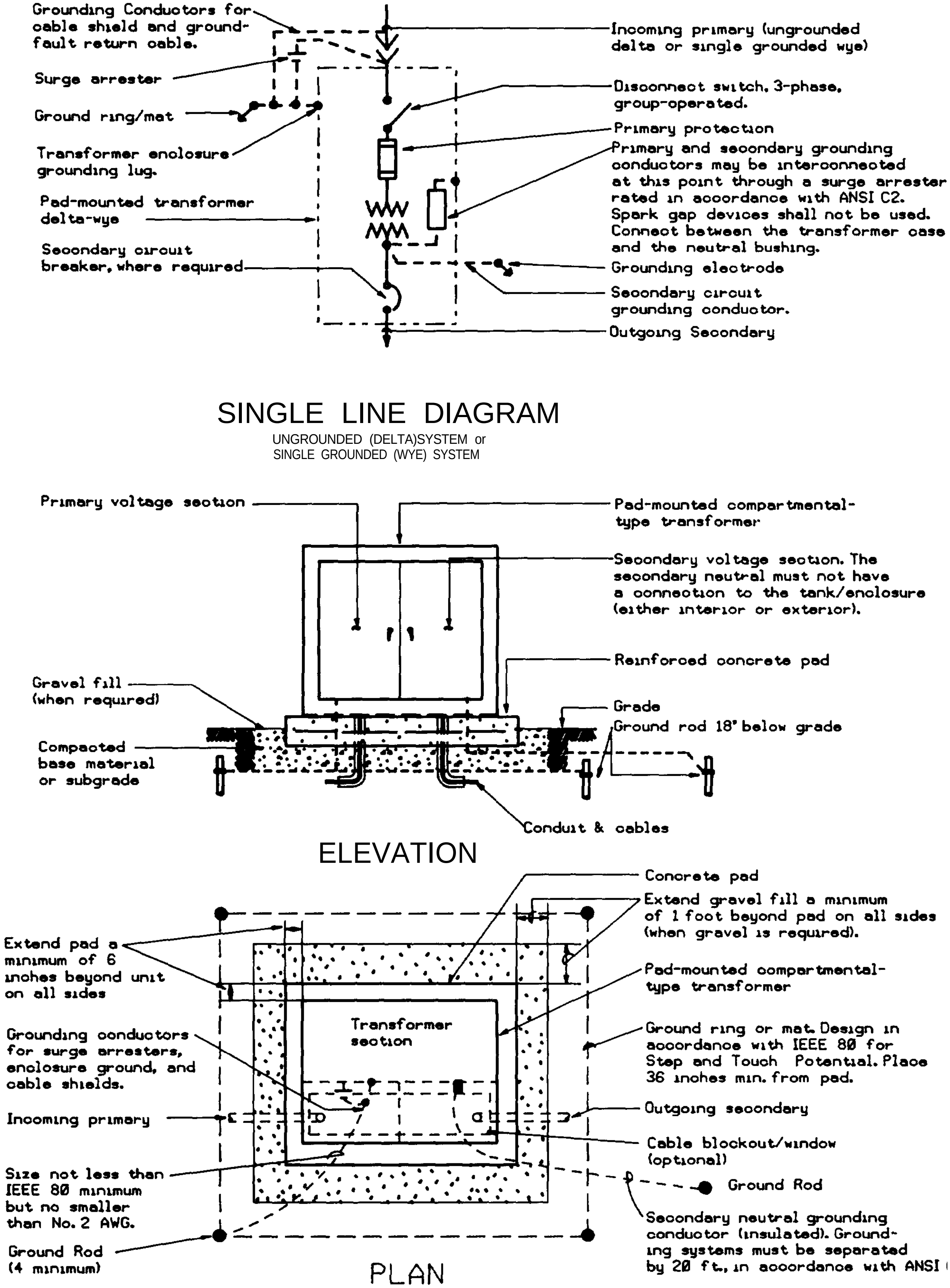


Figure 8-3. Pad-Mounted Compartmental Transformer Installation.

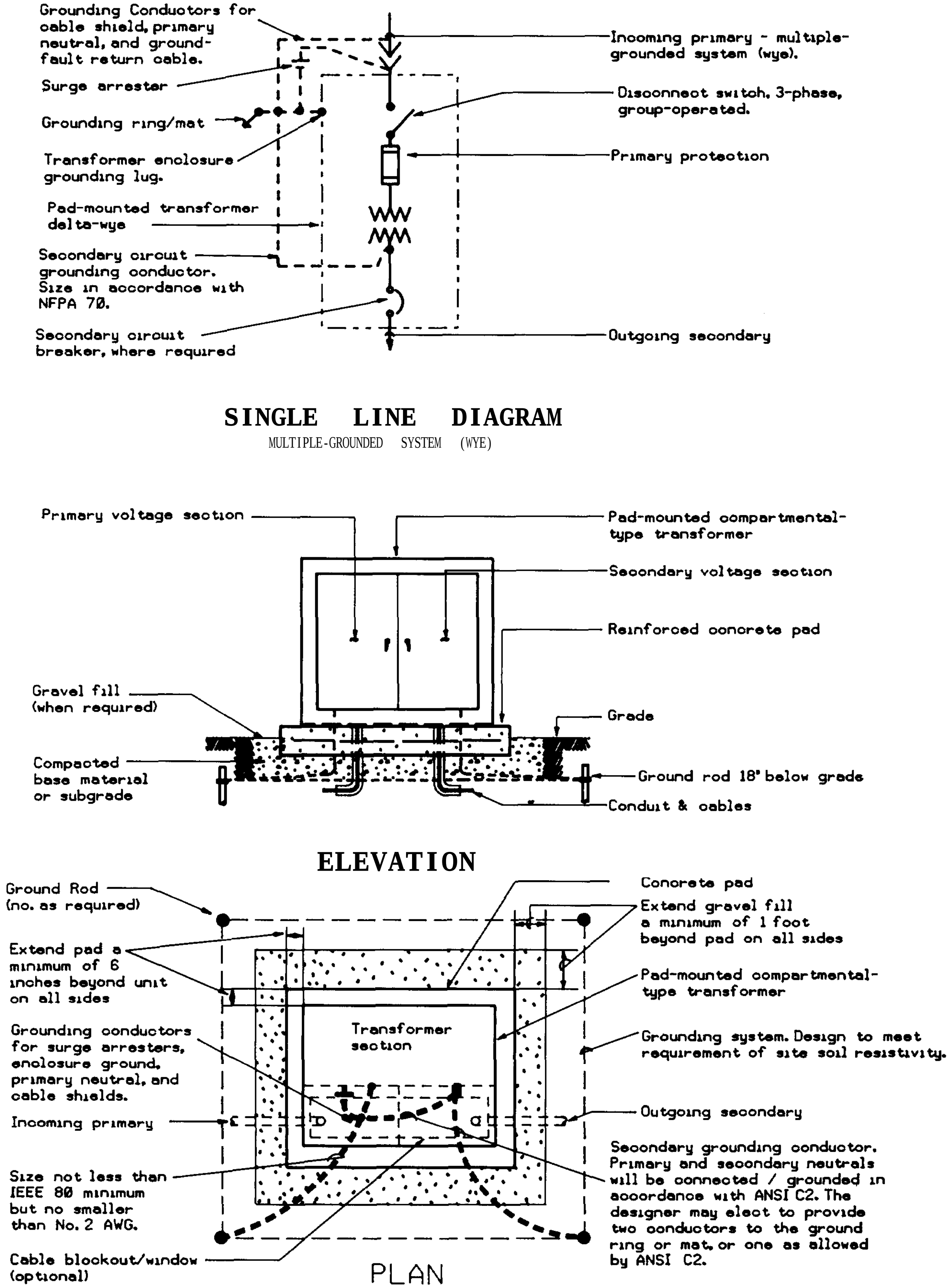


Figure 8-4. Secondary Unit Substation Transformer Installation.

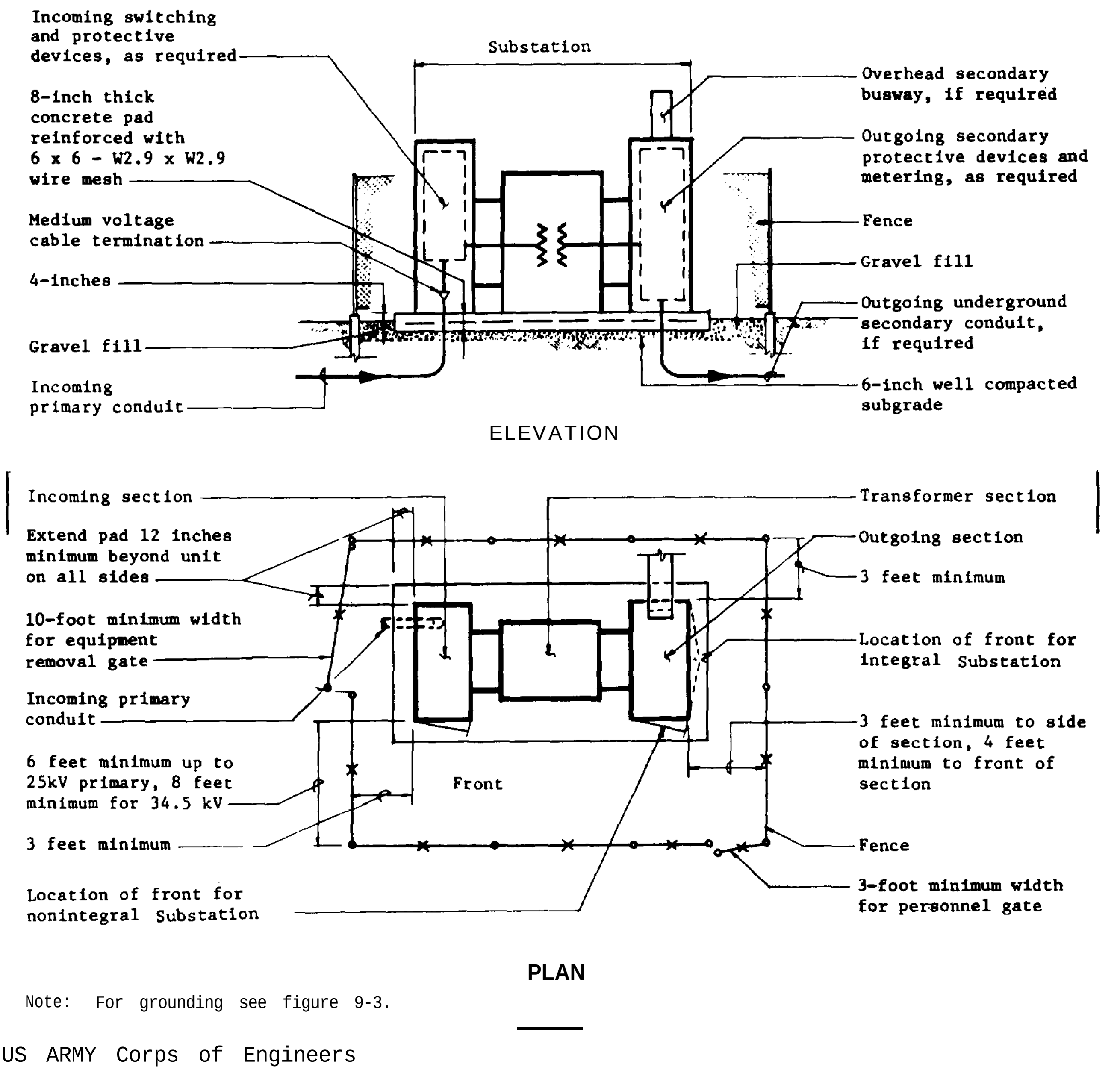


Figure 8-5. Secondary Unit Substation Transformer Installation.

to meet the criteria contained in chapter 4, as applicable.

8-4. Transformer Dielectrics.

In addition to the guidance listed below, the dielectric system will be selected based upon cost, the transformer's location within the building, the available space (liquid-filled units tend to have larger front-to-back dimensions, due to their radiators, than dry-type units), and the HVAC system in the room (dry type units tend to have higher losses than liquid-filled units). All dielectrics specitied must meet the requirements of 40 CFR Part 761; "Polychlorinated Biphenyls (PCBs), Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions."

a. Mineral oil. Mineral oil transformers will be used for outdoor installations only. Mineral oil is the preferred dielectric for outdoor installations.

b. Less-flammable liquid. Less-flammable liquid transformers may be used either outdoors or indoors, and will be installed in accordance with MIL-HDBK-1008A. Acceptable less-flammable liquids are limited to high-molecular-weight hydrocarbons and dimethyl silicone. Where less-flammable liquid transformers are proposed, a cost analysis will be provided which covers the acceptable alternatives and indicates that the most cost effective transformer dielectric material has been selected. Costs will include all features necessary to provide a proper installation, including vaults, curbs, drains, exterior screening, interior floor space, and additional wiring as applicable.

c. Nonflammable fluid. Nonflammable fluids will not be used since there are no nonflammable fluid transformer dielectrics that are not toxic. Tetrachloroethylene (perchloroethylene) insulating fluid will not be used in any electrical equipment since the Environmental Protection Agency (EPA) has classified it as hazardous waste. However, tetrachloroethylene may be used as a cleaning agent during a retrofilling process provided the transformer is not located in an occupied space, has a low probability of overheating, and proper safety precautions are taken. Also, 1, 2, 4-trichlorobenzene (TCB) will not be used as an insulating fluid since it is a possible carcinnogen. TCB may be used as a cleaning agent during the retrofilling process.

d. Existing dielectric hazards. The following will be performed when the dielectric composition of an existing transformer is not listed on the transformer nameplate or cannot be confirmed through procurement records:

(1) The dielectric will be verified either through the manufacturer's records or sample testing.

(2) If the dielectric is determined to be listed by EPA or NIOSH as a hazardous chemical (PCB, TCE/PCE, TCB, or Freon 113), a cost-risk analysis for each structure will be performed. The potential for catastrophic failure of the equipment will be determined for its design life using industry reliability data such as IEEE Std. 500. The consequences of failure will be analyzed and the costs to mitigate the consequences will be estimated. The cost of replacement or retrofill will be compared to the cost of mitigation. Costs to replace or retrofill will include costs for changing the type of dielectric, including relocation or physical isolation of the equipment.

(3) Where the cost-risk analysis requires elimination of the risk, replacement and retrofilling of equipment will be evaluated to determine which is the most cost-effective.

(4) The hazardous chemical risk will be eliminated for those facilities which are mandatory for national security.

(5) The contract specifications will mandate that the contractor (or subcontractor) is or will be certified in the current EPA regulations for handling, storage, transportation, disposal, clean-up, safety and health hazards. The contract specifications will require that retrofitting of PCB contaminated equipment will result in a dielectric with less than 50 ppm PCB.

8-5. Transformer Characteristics.

a. Capacities. Capacities will be in accordance with the standard sizes listed in table 8-1. Padmounted compartmental units are not available for ratings of less than 25 kVA for single-phase units or 75 kVA for three-phase units. Transformer capacities selected will provide a rated capacity equivalent to not less than 90 percent of the load requirement calculated in accordance with guidelines covered in chapter 2, except that distribution transformers serving Family Housing Units will be sized in accordance with the demand factors given in Appendix A. ANSI loading factors may need to be taken into account.

b. Transformer life. Transformer life is dependent upon the thermal aging of the transformer. Normal life expectancy is based on operating transformers continuously at rated capacity to the limiting continuous duty temperature of the insulation. Thus the transformer operating temperature is the sum of the temperature rise (the increase in temperature of the transformer due to the load) and the ambient temperature (average temperature of the immediate air outside the transformer).

(1) *Load duration.* Aging of a transformer is a function of time and temperature. Transformers may be operated above rated load for short periods provided units are operated for much longer periods at loads below these limits, since thermal

Table 8-1. Transformer Standard Base kVA Ratings.[8]

Single-phase				Three-phase			
3	75	1250	10 000	15	300	3 750	25-000
5	100	1667	12 500	30	500	5 000	30 000
10	167	2500	16 667	45	750	7 500	37 500
15	250	3333	20 000	75	1000	10 000	50 000
25	333	5000	25 000	112-½	1500	12 000	60 000
37-½	500	6667	33 333	150	2000	15 000	75 000
50	833	8333		225	2500	20 000	100 000

*Reprinted with permission from ANSI/IEEE Standard 141-1986, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants, copyright 1986 by IEEE. (Table 68).

aging is a cumulative process and there is a time lag in insulation temperature rise. Table 8-2 indicates loads consistent for normal life expectancy at a 30 degrees C average ambient temperature. Table 8-3 may be used for approximating the loads permitted at other ambient temperatures, or the designer may use the tables in the applicable ANSI standards. Correction factors apply only from 0 degrees to 50 degrees C. Temperatures not in this range must be checked with the manufacturer. For further discussion on loading of transformers, see ANSI standards shown in table 8-3 plus IEEE Std C57.91 for 65 degrees C operation of overhead transformers.

(2) *Temperature ratings.* Transformers are rated for a hottest-spot temperature which will give normal life expectancy based on rated kVA loading.

(a) Temperature rise. The temperature rise specified will be 65 degrees C for liquid-filled transformers having a 120 degree C insulation and 150 degrees C for ventilated dry-type transformers having a 220 degree C insulation. If thermally upgraded insulation (greater winding temperature rise rating) is specified, then the transformer will have a longer life at rated capacity and will have more overload capacity. For example, liquid-filled transformers specified to have a 55 degrees C temperature rise at rated kVA and to have an insulation upgraded to 65 degrees C (55 degrees/65 degrees rise) can carry continuously 122 percent of rated kVA. Likewise ventilated dry-type transformers with 220 degrees C insulation having 80 degrees C temperature rise can carry continuously 135 percent of rated kVA Thermal upgrading provides increased temperature rating or extended life at rated capacity. Thermal upgrading will not be specified for dry-type transformers and will be required for liquid-filled transformers only at main electric supply stations.

(b) Ambient. Since the temperature classification of the insulation system is a function of the ambient temperature, the ambient temperature very largely determines the load which can reasonably be carried by transformers in service. An average ambient temperature of 30 degrees C is used as the basis for nameplate ratings. Average ambient temperatures for the actual cooling air are then based on daily operation and the maximum ambient operating temperature in any 24-hour period can be no more than 10 degrees C above the average ambient temperature. The Using Agency will be contacted to determine the average ambient temperature if ANSI load factors are taken into account in transformer loadings. Most load estimates are sufficiently conservative

Table 8-2. Daily Allowable Peak Loads for Normal Life Expectancy.[a]

Peak load duration hours	Mineral-oil, self-cooled (65 C Rise)			Dry-type, self-cooled, (150 C Rise)		
	Allowable peak load in percent of rated capacity following and followed by the indicated percent constant load[b]					
	50%	70%	90%	50%	70%	90%
l/2	200	195	173	149	143	133
1	183	172	153	128	125	121
2	157	150	134	116	115	114
4	134	130	120	110	110	109
8	118	116	110	106	106	105

[a]This material is reproduced with the permission of the American National Standards Institute from the ANSI Standards entitled "Guide for Loading Mineral Oil-Immersed Power Transformers Up To and Including 100 MVA", IEEE Std C57.92, copyright 1981 and "Guide for Loading Dry-Type Distribution and Power Transformers", IEEE Std C57.96, copyright 1989.

[b]At 30°C ambient temperature.

Table 8-3. Loading on the Basis of Ambient Temperatures.[a]

Transformer	For each degree C that the average ambient temperature is above or below 30° C the percent of rated kVA shall be: Increased for lower ambient	Decreased for higher ambient
Mineral-oil-immersed, self-cooled (65 C Rise)	1.5	1.0
Dry-type, self-cooled ventilated (150 C Rise)	0.35	0.35

[a]This material is reproduced with the permission of the American National Standards Institute from the ANSI Standards entitled "Guide for Loading Mineral-Oil-Immersed Power Transformers Up To and Including 100 MVA", IEEE Std C57.92, copyright 1981 and "Guide for Loading Dry-Type Distribution and Power Transformers", IEEE Std C57.96, copyright 1989.

to take into account any nameplate derating for units located in high ambient temperature areas. Low ambient temperature should not be a deciding factor in sizing of transformers, except where the installation has an average daily ambient of 20 degrees C or less.

(c) *Use of ANSI loading factors.* The influence of operating temperatures and load durations on transformer life may have to be taken into account in sizing transformers.

c. Cooling provisions. The rated capacities of 750 kVA and larger transformers can be increased by the addition of cooling fans, with the exception of pad-mounted compartmental units. ANSI C57.12.10 covers both the initial installation of cooling fans and the provisions which permit addition of future forced-air-cooling. Fan cooling can be controlled by either top-liquid temperature or winding temperature. The type of control will be left to the option of the manufacturer.

(1) *Main electric supply stations.* Forced-air-cooling will be provided in accordance with the criteria of chapter 4.

(2) *Secondary unit substation transformers.* Since secondary unit substation transformers supply electrical energy for direct utilization by motors, lights, and other devices, initial forced-air-cooling is not necessary is most cases. Provisions for addition of future forced-air-cooling will be provided only when such cooling equipment is a cost effective way to satisfy future load increases.

d. Basic impulse levels. Insulation characteristics for voltage surges of high magnitude but short duration, such as lightning or switching surges, are determined by impulse tests. The most common test is the application of either a 1.2 x 50 microsecond or a 1.5 x 40 microsecond full impulse voltage wave, dependent upon the industry specification. The crest value of the voltage wave is called the basic impulse insulation level (BILL) of the equipment involved. Standard basic impulse insulation levels have been established for each voltage reference class; however, equipment rated 15 kV and below is often built to a so-called "distribution-class" BIL rather than to the standard or "power-class" BIL. The distribution class BIL requirement is even lower for ventilated dry-type transformers than for liquid-filled transformers as shown in table 8-4, although BIL levels equivalent to those for distribution-class liquid-filled units can be obtained for some voltages at a relatively small cost increase. Ventilated dry-type transformers will always be provided with a BIL rating equivalent to liquid-filled units of the same rating. Use of external devices such as surge arresters to provide an adequate BIL protective level is not acceptable.

e. Transformer connections. The wye-wye connection of two-winding transformers requires that a fourth wire (neutral or ground) be installed throughout the length of distribution lines, and the solid grounding of the primary and secondary windings of transformers. Loss of either the primary or secondary ground and unbalanced loading can cause interference on communication circuits and result in excessive heating of the tanks of three-phase transformers. For those reasons, the wye-wye connection of two-winding transformers will be avoided whenever possible. A delta primary connection eliminates objectionable odd harmonic paths and a wye-secondary connection pro-

Table 8-4. Basic Impulse Insulation Levels

		Basic impulse level (BIL) kV			
		Liquid-immersed units		Ventilated dry-type units	
Insulation reference class kV	Normal duty for insulation reference class	C57.12.00[a] requirement for power class	C57.12.00[a] requirement for distribution class[c]	C57.12.01[b] requirement	Available and mandatory
5	60	75	60	30	60
15	110	110	95	60	110
25	150	150	150	110	150
35	200	200	200	150	200

[a]Reprinted with permission from IEEE Std C57.12.00-1987 "Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.

[b]Reprinted with permission from IEEE Std C57.12.01-1969 "Standard General Requirements for Dry-Type Distribution, Power, and Regulating Transformers.

[c]Rating also applicable to primary and secondary units substations.

vides enhanced protection against low magnitude ground fault currents. Therefore, connections will be delta-wye, except where other connections are technically advantageous. When wye-wye connections cannot be avoided, a three-winding transformer will be specified. The tertiary winding will be specified to be delta connected to provide a path for the third harmonic currents. Elimination of ferroresonance is not an acceptable reason for providing a wye primary connection.

f. Impedance. Standard impedances will be used to the greatest extent possible for reasons of economy. However, industry standards do not specify the percent impedance for overhead transformers or for pad-mounted compartmental distribution transformers of 500 kVA and less. Manufacturers supply these units with such low impedances that normal interrupting duties for protective devices may be inadequate. For this reason, it may be necessary to specify minimum impedances for three-phase pad-mounted compartmental and overhead type transformers. These impedances will be no more than are required by industry standards for secondary unit substations of the same kVA rating as shown on table 8-5. Where the designer feels that circumstances warrant specifying a minimum impedance for overhead and single-phase pad-mounted compartmental units, the values of table 8-5 should be used. Values greater than 1.5 percent for transformers 75 kVA and smaller are not justified.

g. Voltage taps. Power transformers for use in transmission to distribution substation applications are normally provided with manual voltage taps at no additional cost. Since taps are not always required by NEMA or ANSI standards for smaller distribution transformers, the specifications will require taps on transformers where they are available.

h. Factory tests.

(1) *Standard manufacturer's tests.* "Routine" factory tests, in accordance with IEEE Std C57.12.00, will be specified for all transformers. Optional "design" and "other" tests, in accordance with IEEE Std C57.12.00, will be specified for transformers supplying critical facilities. "Routine" tests are tests made for quality control by the manufacturer on every transformer, or representative samples, to verify during production that the transformer meets the design specifications. "Design" tests are those tests made to determine the adequacy of the design of a particular type, style, or model of transformer to meet its assigned ratings and to operate satisfactorily under normal service conditions or under special conditions if specified; and to demonstrate compliance with appropriate standards of the industry. Design tests are made only on representative samples. "Other" tests are tests so identified in individual product standards which may be specified by the purchaser in addition to routine tests.

(2) *ANSI impulse tests.* A reduced wave, chopped wave, and full wave impulse test, in accordance with IEEE Std C57.98 will be required on all transformers rated 200 kVA and above. Since such a test is mainly for quality control, tests must be run for each transformer. Prototype tests do not indicate quality control deficiencies.

(3) *Optional NEMA impulse tests.* These tests are expensive and will not be provided for distribu-

Transformer kVA	Percent impedence, when primary voltage is less than 15 kV[a]	Maximum three-phase short circuit amperes[b]: 208Y/120 volts, From transformer	208Y/120 volts, 100% motor contribution	480Y/277 volts, From transformer	480Y/277 volts, 100% motor contribution
112.5	2.0	15,600	1,300	6,800	500
150	2.0	20,800	1,700	9,000	700
225	2.0	31,300	2,000	13,600	1,100
300	4.5	18,500	3,300	8,000	1,400
500	4.5	30,900	5,600	13,400	2,400
750	5.75	36,200	8,300	15,700	3,600
1,000	5.75	48,300	11,100	21,000	4,800
1,500	5.75	72,500	16,700	31,400	7,200
2,000	5.75	96,600	22,200	41,900	9,600

[a] These impedance values are reproduced by permission from NEMA Standard Publication No. 210-1970(R 1976) entitled "Secondary Unit Substations."
[b] Transformer short circuit current based on unlimited utility company contribution.

Table 8-5. Standard Secondary Unit Substation Percent Impedances.

tion transformers. These tests will be specified for large transformers only (50 MVA and larger) or where reduced insulation is provided on transformer windings rated 115 kV and above. Optional NEMA impulse tests include either a nominal test sequence consisting of a reduced full wave, two chopped waves, and one full wave or a combined test sequence which interposes two or more front-of-wave tests between the reduced full wave and the two chopped wave tests on the nominal test sequence.

8-6. Amorphous Metal-Core Transformers.

Amorphous metal-core transformers will be used only where it can be demonstrated that the life-cycle cost of the installation is less than or equal to standard transformers. It has been reported by some studies that amorphous metal-core transformers can save energy by reducing no-load losses by 60 to 70 percent. However, since the percent impedance is decreased, the short-circuit current will increase proportionally. Therefore, the electrical distribution equipment associated with amorphous metal-core transformers must be increased in size to withstand the increased short-circuit current. The resulting energy conservation may be offset by the increased withstand ratings.

8-7. Transformers at Air Force Installations.

a. Single phase, self-cooled, with provisions to increase capacity if externally cooled, delta-wye if connected for three-phase service. Nonflammable liquid or epoxy insulation is preferred. However, high tire point liquid or oil insulation may be provided if they are approved by the HOST/REQ CMD.

b. Three-phase pad-mount transformers, delta-wye connected, are preferred in lieu of single-phase transformers where the load can be served by a single three-phase transformer and where the transformer can be easily repaired or replaced upon failure of any winding and the load can be interrupted during such repair period.

c. Four single-phase units may be provided where such spare capacity is required for 100 percent spare transformer capacity on site. Multiple installation of like substations for two or more blocks of load at the same general installation shall employ three-phase transformers in parallel or through secondary bus tie.

d. If pole mounting is required, radial brackets or cluster mounting is preferred in lieu of crossarm or platform mounting for sizes 3 to 75 kVA.

e. Avoid locating transformers adjacent to building front entrances in landscaped areas. Prefer pad-mounting at the rear or side area where feasible.

f. Polychlorinated Byphenyls (PCB) contaminated transformers shall be disposed of in accordance with the latest requirements of the Environmental Protection Agency (EPA) as they are removed from service.